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THE
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VOL. LVII MAY, 1947. No. 5

ONE-STAGE RESECTION OF TOTAL CERVICAL ESOPHAGUS, LARYNX, BASE OF TONGUE, HYPOPHARYNX, CERVICAL TRACHEA AND BILATERAL CERVICAL LYMPH NODE CHAINS FOR CARCINOMA PRIMARY IN THE CERVICAL ESOPHAGUS; RECONSTRUCTION OF CERVICAL ESOPHAGUS.*†

ALEXANDER BRUNSCHWIG, M.D., and EDWARD CAMP, M.D.,
Chicago, Ill.

The purpose of this report is to record a successful one-stage resection of the entire cervical esophagus, hypopharynx, larynx, cervical trachea, and cervical lymph nodes bilaterally for carcinoma arising in the upper portion of the cervical esophagus just behind the larynx. The esophagus was reconstructed by a cutaneous flap.

CASE REPORT.

M. S., white female, 33 years of age. Admitted Oct. 6, 1946, complaining of difficulty in swallowing for four months. Upon interrogation, she stated that she believed there was some difficulty in swallowing for eight or nine years; she could not swallow tablets, and if attempts were made, stroking the neck was necessary to "get them down." The difficulty in swallowing particulate matter increased noticeably in June, 1946, and hoarseness developed, with pain mainly on the right side of the neck radiating into the mandible. There had been loss of 20 pounds in weight during the previous several months. Esophagoscopy revealed an ulcerating lesion at the entrance of the cervical esophagus situated posterior to the larynx. Biopsy revealed squamous cell carcinoma. Roentgen ray examination of the lungs was negative.

*From the Department of Surgery, University of Chicago.

†This work was aided by the Charles H. and Mary F. S. Worcester Fund.

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The situation was managed as follows:

Oct. 12, 1946: Pezzar catheter gastrostomy (technique previously described).[1]

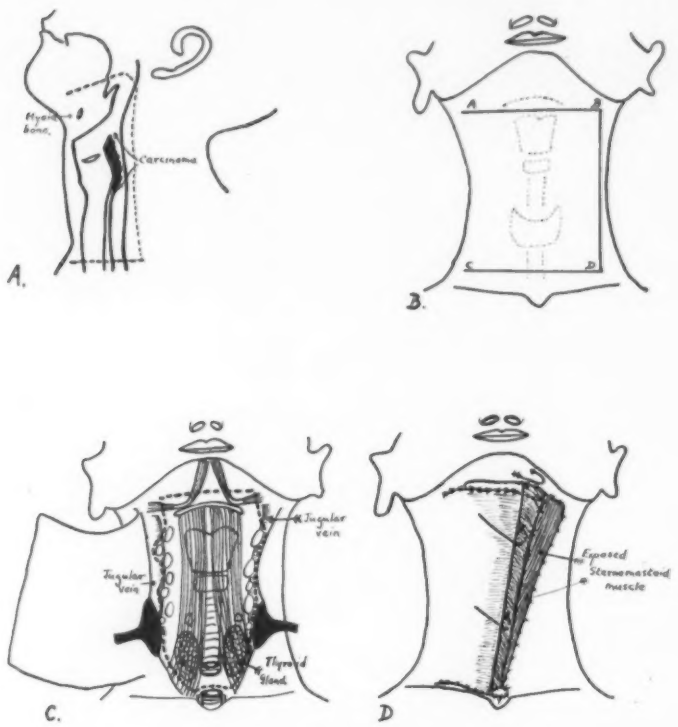

Fig. 1A. Diagram showing extent of resection envisaged.

Fig. 1B. Diagram showing large rectangular flap **ABCD**, skin and platysma, elevated to exposure of structures in the neck. Chin sharply elevated.

Fig. 1C. Dotted line indicates limits of excision. Both chains of cervical lymph nodes, larynx, cervical trachea, hypopharynx, cervical esophagus, strap muscles, hyoid bone and attached muscles, upper portions of thyroid poles were removed en masse. Jugular veins and carotid arteries were not injured or ligated. The inferior segments of trachea and esophagus were sutured into the lower angle of the wound.

Fig. 1D. The skin and platysma flap have been brought back over the neck, the upper border sutured to the posterior wall of the mesopharynx and then folded over to the patient's right, beneath the left sternomastoid muscle, forming an open trough. The bottom of this trough was sutured to the sternomastoid muscle. The skin margin on the left side of the neck was sutured to the sternomastoid muscle. An elongated triangular denuded area over the sternomastoid muscle remains. This was later covered by grafts.

Oct. 14, 1946: Resection (general anesthesia—avertin and intratracheal ether).

The incision to elevate a large flap is shown in Fig. 1. The right and left cervical chains of lymph nodes were dissected upward en masse and off the jugular veins. The nodes did not appear to be involved by metastases; areolar tissues con-

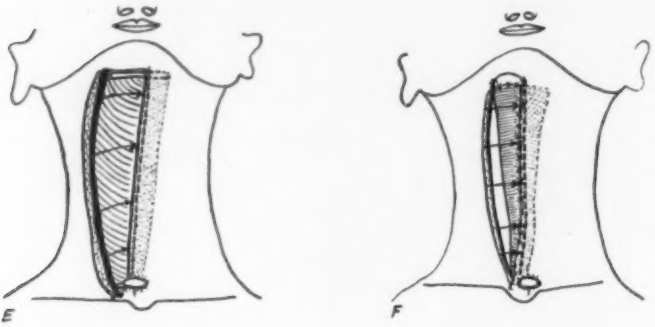

Fig. 1E. Closure of right portion of reconstructed cervical esophagus. Incision made through skin and platysma, inner wound margin sutured to split border of trough.

Fig. 1F. Closure of skin over completed esophagus.

necting them with the larynx were preserved. The upper poles of the thyroid gland were transected and ligated. All the strap muscles were divided in the lower portion of the neck. The trachea was transected as low as possible in the neck. The esophagus was transected at a level almost in the upper mediastinum. The upper segments of esophagus and trachea were dissected upward and the larynx and hypopharynx freed on all sides. A transverse incision was made above the hyoid bone after division of the digastrics and the pharynx entered through the base of the tongue. All structures, *i.e.*, lower pharynx, cervical esophagus, trachea, larynx, hyoid bone, strap muscles and both chains of cervical lymph nodes were removed en masse. Hemostasis. A cutaneous gutter extending from base of tongue to root of the neck was then fashioned with the cervical flap (see Fig. 1D) and sewed

to pharyngeal and esophageal openings with interrupted chromic catgut sutures. The trachea was sutured to the lower angle of the cutaneous wound. A tracheotomy tube was inserted (see Fig. 3).

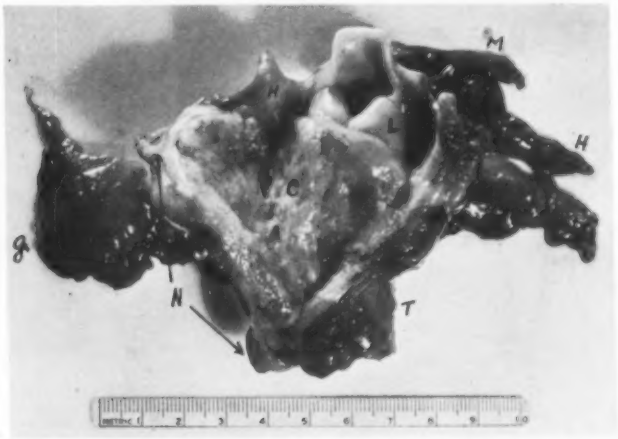

Fig. 2. Photograph of surgical specimen showing **L**, larynx with edematous arytenoid regions; **H**, hyoid bone; **N**, cervical esophagus and hypopharynx; **C**, carcinoma on anterior aspect of cervical esophagus, infiltrating toward larynx; **G**, left chain of cervical lymph nodes; **H**, right chain of cervical lymph nodes; **T**, upper portion of right lobe of thyroid; **M**, musculature of base of tongue. The trachea cannot be seen on the photograph, being on the opposite aspect of the specimen.

The surgical specimen is depicted in Fig. 2. Histologic study revealed squamous cell carcinoma. No lymph nodes examined showed metastases.

Convalescence was essentially uneventful.

Nov. 30, 1946: Pinch grafts were applied to the granulating surface on the left side of the neck to cover the denuded anterior surface of left sternomastoid muscle.

Dec. 28, 1946: Under local anesthesia a linear incision through skin and platysma was made along the right border of the gutter in the neck to elevate flaps for complete closure

of the cervical esophagus. The right border of this incision was elevated as a flap to cover the tube externally (see Fig. 3).

The third day after this operation a large hematoma developed on the right side of neck with partial separation of the

Fig. 3. Photograph showing partially reconstructed cervical esophagus from cutaneous flap. T. tracheotomy. Dotted line shows locus of incision that was subsequently made to complete closure of trough.

lower edges of the fresh wound, although the inner esophageal closure remained intact.

Jan. 21, 1947: Dermatome skin grafts to raw area in right side of neck.

By this time the patient was able to swallow liquid and semisolid foods by mouth. She had been nourished entirely

by gastrostomy tube since Oct. 12, 1946, and had gained three kilos in weight.

Feb. 16, 1947. Pezzar catheter pulled out of stomach.

Feb. 17, 1947: Regular diets taken in liberal quantities by mouth without difficulty in deglutition. Patient discharged from the hospital Feb. 20, 1947 (see Figs. 4 and 5), having gained 25 pounds.

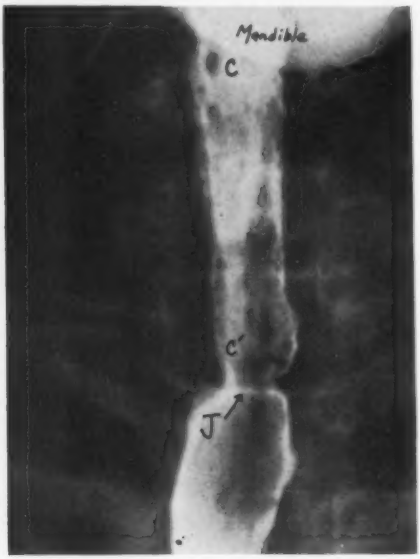

Fig. 4. X-ray photograph of patient swallowing barium, distending the reconstructed cervical esophagus, CC'. J, junction of reconstructed esophagus with thoracic portion at level of first thoracic vertebra. Solid food of any type was swallowed without difficulty.

DISCUSSION.

The experience reported above indicates the extent to which surgical attack upon esophageal cancer in the neck is possible. The surgical principles are the same as in the cases reporter by Wookey[2] and by Brunschwig.[3,4] The unfortunate aspect of the situation is the necessity of having sacrificed

the larynx, which was not directly involved, but removal of the neoplasm required this.

The history of difficulty in swallowing for eight or nine years previously strongly suggests that a benign squamous cell papilloma was present which subsequently underwent

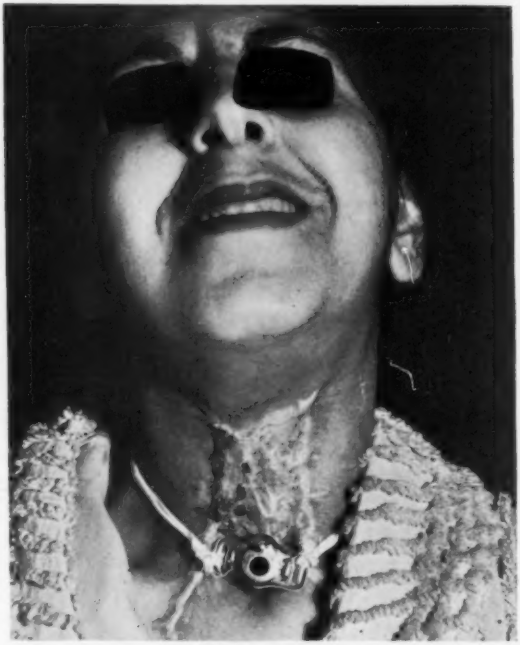

Fig. 5. Photograph of patient after completion of reconstruction of cervical esophagus as described in text. Tracheotomy tube in place. Condition at time of discharge.

malignant transformation. This again emphasizes the necessity of removal of such growths in the oral cavity and upper air and food passages.

Not the least interesting feature of the postoperative sta-

tus of the patient is the fact that, although the entire cervical esophagus is composed of a skin and subjacent fatty tissue, and is devoid of contractable musculature, there is no difficulty in deglutition. This obtains in spite of the fact that prior to closure of the reconstructed cervical esophagus, no special deglutition exercises were carried out by the patient.

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ANOMALIES OF THE INTERNAL CAROTID ARTERY AND ITS BRANCHES; THEIR EMBRYOLOGICAL AND COMPARATIVE ANATOMICAL SIGNIFICANCE. REPORT OF A NEW CASE OF PERSISTENT STAPEDIAL ARTERY IN MAN.*†‡

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INTRODUCTION.

Malformations of the internal carotid artery and its branches are rare but interesting from the embryological and comparative anatomical point of view. The reports of such anomalies are scattered throughout the literature and often not easily accessible. The only two comprehensive representations of the subject by R. Quain (1844) and Krause (1876) are outdated.

Almost all the anomalies can be explained as deviations from the normal development; many of them represent conditions which are regularly found in lower mammals or other vertebrates.

It is the purpose of this paper to collect all the cases thus far known, with the exception of those concerning the ophthalmic and cerebral arteries and to explain them according to the present status of our knowledge of the development and the comparative anatomy of the cranial vessels. In addition, a new case of persistent stapedial artery in man is reported.

Very little is found in otological textbooks or in the otological literature in general about the anomalies in question,

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*Presented as a Candidate's Thesis to the American Laryngological, Rhinological and Otological Society, Inc.

†From the Department of Otolaryngology of the Columbia University College of Physicians and Surgeons, and the Presbyterian Hospital.

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although some of them are also of practical surgical importance.

In order to understand the somewhat complicated developmental deviations, a brief outline of the normal development

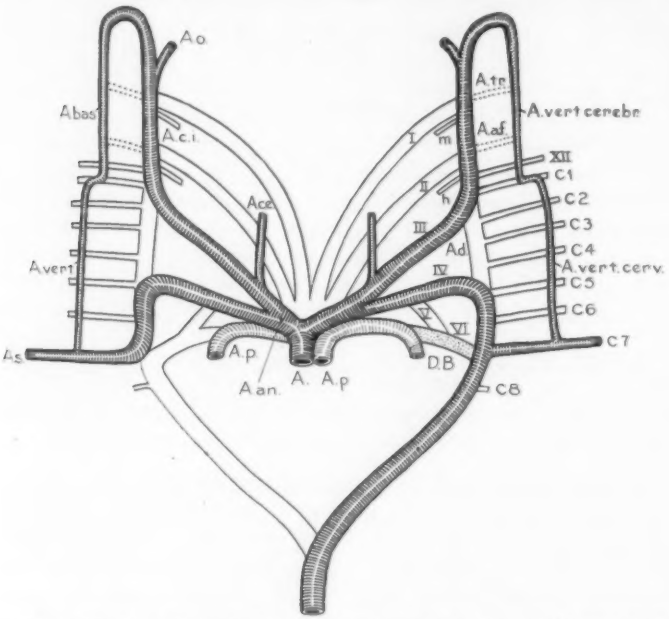

Fig. 1. Diagram demonstrating the development of the cranial arteries in man. **A.**, aorta; **A.a.f.**, acusticofacial artery; **A.an.**, innominate artery; **A.bas.**, basilar artery; **A.c.e.**, external carotid artery; **A.c.i.**, internal carotid artery; **A.d.**, dorsal aorta; **A.o.**, ophthalmic artery; **A.p.**, pulmonal artery; **A.s.**, subclavian artery; **A.tr.**, trigeminal artery; **A.vert.**, vertebral artery; **A.vert. cerebr.**, cerebral vertebral artery; **A.vert.cerv.**, cervical vertebral artery; **c1-c8**, first-eighth cervical segmental artery; **D.B.**, Ductus Botalli; **I-VI**, first-sixth aortic arch; **XII**, hypoglossal artery.

of the cranial vessels shall precede the discussion of the anomalies.

THE DEVELOPMENT OF THE CRANIAL ARTERIES.

The human embryo, like that of all other vertebrates, possesses a row of six visceral arches, separated externally

by clefts, internally by entodermal pockets or pouches. Its primitive vascular system is in conformity with this fundamental phase. Six strong branches arise on each side ventrally from the aortic sac (bulbus arteriosus), course in the visceral arches and terminate dorsally in the dorsal aorta of the corresponding side (see Fig. 1). The aortic arches develop in their order from front to back, but the six pairs are never all present at the same time (see Figs. 2 and 3).

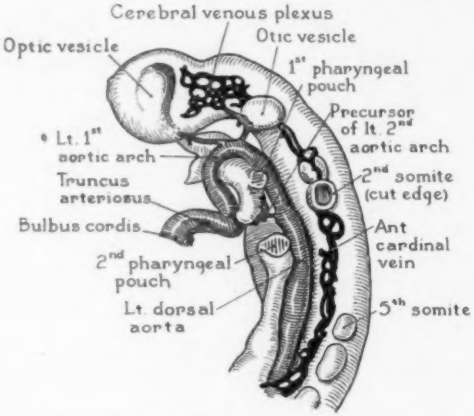

Fig. 2. Wax plate model of the arterial and venous system of an embryo with 22 somites (after Congdon: Contr. to Embryol., 14:48, 1922).

The first undergoes involution about the time the fourth is complete, and the second disappears before the sixth (pulmonary) arch has become a continuous channel. The phase of branchial arch arteries persists until about the 13 mm. stage, but much later, and even in the adult, the basic branchial pattern is still recognizable.

In embryos longer than 13 mm., the portion of the dorsal aorta between the third and fourth arch on each side and the segment of the right dorsal aorta between the fourth arch and its junction with the left dorsal aorta disappears. The aortic sac, its left horn, and the left fourth arch artery form

the arch of the definitive aorta. The right horn of the aortic sac becomes the A. anonyma. The proximal part of each third arch artery becomes the common carotid artery and its distal part the root of the internal carotid artery. The stem of the internal carotid artery is formed by the original dorsal aorta between the third and first arch.

In embryos of about 4 mm., the internal carotid artery extends far beyond the first branchial arch artery. It runs

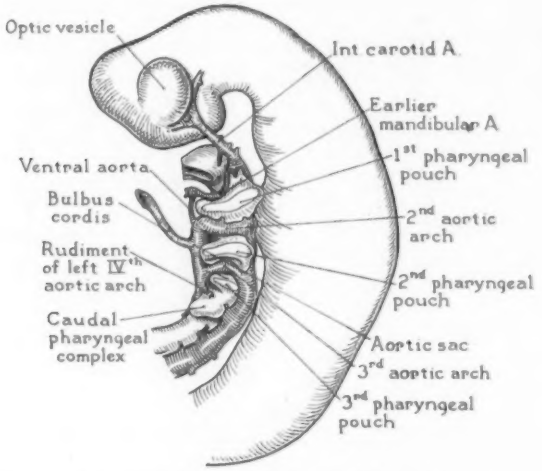

Fig. 3. Wax plate reconstruction of the arterial system of an embryo of 4 mm. (after Congdon: Contr. to Embyol., 14:48, 1922).

forward, then turns dorsally and eventually caudally. It gives off the ophthalmic branch to the eye vesicle and then divides into an anterior (aa. choriodalis ant., cerebri ant., and media) and a posterior branch. The latter turns caudally in order to join the cerebral vertebrals (q.v.). It originally continues into the posterior cerebral artery but later becomes the posterior communicating artery.

According to Congdon, the external carotid arteries arise as new branches from the ventral aspects of the third arch arte-

ries. They probably link up with endothelial channels left by the retrogression of the first and second arch arteries. The first anlage of the external carotid arteries is situated near the midline, but in the course of the development the artery is gradually shifted laterally. The points of origin of the external carotid arteries divide the third arch arteries into common and internal carotid segments. In embryos of 14 mm. among the branches of the external carotid, the aa. thyroidea superior, lingualis and occipitalis are present. In embryos of 15.5 mm., the auricularis posterior and temporalis superficialis have already developed.

In the segmented part of the body the dorsal aorta and the internal carotid artery give off segmentally arranged dorsal branches, the so-called segmental arteries. In the nonsegmented part of the head, cranially to the somites, similar dorsal branches, the so-called presegmental dorsal arteries, are given off to the hind-brain. They have been found in young human and animal embryos and seem to represent connections between the internal carotid arteries and the cerebral vertebral arteries (q.v.). They run parallel to certain brain nerves (Vth, VIIth and VIIIth), but their relationship to them and also to the visceral arches has not been completely clarified as yet (De Vriese, Oertel, Hochstetter and others).

In the occipital region up to four segmental arteries are formed (Schmeidel). The upper three of these could be called hypoglossal arteries, because they show neighborly relations to the hypoglossal nerve. The fourth lies at the border between the occipital and cervical region, runs with the N. postoccipitalis or cervicalis I, and is called postoccipital or first cervical artery. The hypoglossal arteries become connected with paired longitudinal arteries in the region of the future basilar artery. Even in very early stages they are connected with the caudal end of the internal carotid arteries. At a certain stage, the internal carotid arteries communicate with the dorsal aortae by way of the cerebral vertebral and hypoglossal arteries; later, the cerebral vertebral arteries unite to form the basilar artery. In the caudal prolongation

of the cerebral vertebral arteries the cervical vertebral arteries are formed as longitudinal anastomoses between branches of the cervical segmental arteries. These anastomoses lie outside the spinal cavity; they progress downward to the seventh cervical artery so that after a certain segment has been reached by the anastomosis, the artery above that level atrophies, and eventually the vertebral artery becomes a branch of the seventh intersegmental artery.

The intracranially located cerebral vertebral arteries and the extraspinally located cervical vertebral arteries are originally connected by one of the hypoglossal arteries; later, the connection is taken over by the first intersegmental artery. The spinal branch of this artery represents the portion of the vertebral artery which lies on the arch of the atlas.

The changes which occur in the first and second branchial arches require more detailed description. According to Congdon, after the disappearance of the first and second aortic arches the corresponding visceral arches are each occupied by two successive channels. These may be termed respectively the earlier and later mandibular (see Figs. 1 and 3) and hyoid arteries. The earlier channels lie near the axis of the arch; those appearing later lie close to its caudal border. These arteries all break up in a plexus in the subpharyngeal region. Their current is from the dorsal aorta and they supply the visceral arches. Only the later hyoid artery can be found in more advanced stages and then constitutes the stem of the so-called stapedial artery which runs through the blastema of the stapedial ring. Although the changes taking place in man still await final clarification, it is assumed that they are identical with those found by Tandler in the rat. Here the stapedial artery extends from the second arch into the first arch and connects with the blood vessels originally arising from the first arch. At the height of its development, in embryos of 12-15 mm., the stem of the stapedial artery turns after passing through the stapedial anlage ventrally and traverses the region of the later petrotympanic fissure. The artery ends in three branches which accompany the three branches of the trigeminal nerve (see Fig. 4, A). The upper

or supraorbital branch goes to the area later supplied by the A. meningea media and to the orbita; the infraorbital and mandibular branches, which originate from a common trunk, later become the infraorbital and inferior alveolar arteries. In embryos of 15-17 mm., an anastomotic branch develops

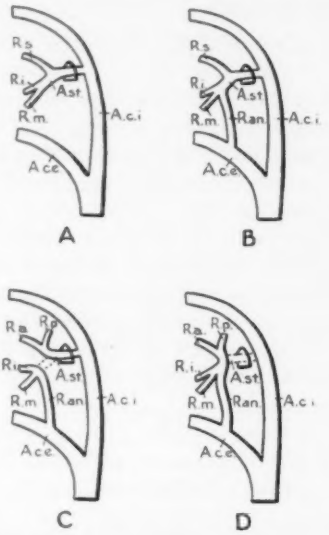

Fig. 4. Diagram showing the developmental changes of the stapedial artery and its branches in man. **A.** embryo of 12-15 mm.; **B.**, embryo of 15-17 mm.; **C**, embryo of 20 mm. (Fisher); **D.**, later stages; **A.c.e.**, external carotid artery; **A.c.i.**, internal carotid artery; **A.st.**, stapedial artery; **R.a.**, anterior branch of the middle meningeal artery; **R.an.**, anastomotic branch between external carotid and stapedial artery; **R.i.**, infraorbital branch of the stapedial artery; **R.m.**, mandibular branch of the stapedial artery; **R.p.**, posterior branch of the middle meningeal artery; **R.s.**, supraorbital branch of the stapedial artery.

between the external carotid artery and the stem of the stapedial artery at the place where the latter divides itself into the infraorbital and mandibular branch. According to Orts Llorca, the anastomosis joins the proximal part of the mandibular branch. This anastomosis becomes later the internal maxillary artery (see Fig. 4, B). The part of the stapedial artery between the internal carotid artery and the origin of

the supraorbital branch atrophies. Finally, all three branches of the stapedial artery are supplied by the external carotid artery (see Fig. 4, D). The A. tympanica anterior, which originates from the internal maxillary artery and goes through the Glaserian fissure into the tympanic cavity, is possibly a remnant of the distal part of the otherwise atrophied stem of the stapediad artery (Tandler).

Fisher found missing in an embryo of 20 mm. the part of the stem of the stapedial artery between the supraorbital branch and the anastomosis with the external carotid artery (so-called descending trunk) (see Fig. 4, C). The stapedial artery gave off an ascending branch which becomes the middle meningeal artery, and then continued forward to the orbit. The internal maxillary artery gave off the two other branches. If these findings should be confirmed as a regular occurrence by other observations, then it could be assumed that the intracranial part of the middle meningeal artery is developed from an ascending branch of the stapedial artery and at an earlier stage than the lower or extracranial part. The latter would be a secondary connection between the stapedial and internal maxillary arteries.

DISCUSSION OF THE ANOMALIES OF THE INTERNAL CAROTID ARTERY AND ITS BRANCHES.

From an embryological point of view, the anomalies can be divided into two main groups: the first comprises those involving the first four aortic arches and the dorsal aorta; the second group comprises anomalies in the regression of the segmental and presegmental dorsal arteries.

Anomalies of the Fourth and Third Aortic Arch and the Dorsal Aorta.

1. Absence of the Internal Carotid Artery. Complete absence of the internal carotid artery is a rare malformation. It has been reported in 11 cases (Tode, Quain, Peugnet, Wyeth, Wernitz, Flemming, Fisher, Lowrey, Poppi, Hindze and Freidmann, Töndury). In all of these, with the exception of Fisher's case, the vessel was absent on one side only.

In the case of Hindze and Freidmann a very rudimentary internal carotid was present. It measured 1.5 mm. in diameter and ended after a short course. The carotid canal in the temporal bone was narrow in some cases (*e.g.*, Tode, Töndury), completely missing in others (*e.g.*, Wyeth, Flemming, Fisher). A circle of Willis was found in all cases, but it showed various anomalies. The ophthalmic artery originated either from the circle of Willis or from the middle meningeal artery. In other instances, however, the middle meningeal artery was given off from the ophthalmic artery and the extracranial part of the middle meningeal artery with the foramen spinosum being absent (Töndury). In many instances anomalies were also observed in other vessels. In Quain's case (*e.g.*) the internal carotid artery was replaced by two branches of the internal maxillary artery which entered the skull through the foramen ovale and rotundum. They joined and formed a single vessel which lay on the inner side of the Vth nerve and gave off the ophthalmic artery and the other intracranial branches of the internal carotid artery. This vascular arrangement is similar to that regularly found in ruminants.

Comparative anatomical and embryological studies (Tandler) show that the internal carotid artery is constantly developed in all classes of mammalia. In a great number of species, however, a secondary obliteration of the vessel takes place during the embryonic or in some cases even the early postembryonic development. The artery has completely disappeared in most ruminants, some carnivores, rodents and other species.

Also in man, a secondary atrophy of the originally normally developed internal carotid artery must be assumed in these cases. In this way only, the presence of the infraorbital and inferior alveolar arteries can be explained, which, as branches of the stapedial artery, must originally have been connected with the internal carotid artery. As already mentioned, sometimes vestiges of the atrophic internal carotid artery are still visible (Hindze and Freidmann).

2. Hypoplasia of the Internal Carotid Artery. This condition has been observed bilaterally by Hyrtl (1836), who found the lumen of the vertebral artery three times larger

than that of the internal carotid artery, and on one side by Guinard and Orr.

3. Separate Origin of the External and Internal Carotid Artery from the Aortic Arch or the Innominate Artery. Only 10 cases have been described (Malacarne, Power, Kosinski, Gottschau, Macalister, Angermayer, Fife, Smirnov, Schmeidel, Boyd). In Malacarne's case two symmetrically formed ascending aortae and aortic arches were present which united behind the esophagus and formed the descending aorta.

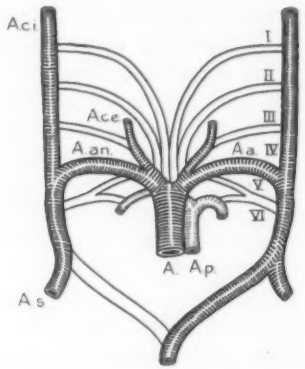

Fig. 5. Diagram showing separate origin of internal and external carotid artery. **A.**, aorta; **A.an.**, innominate artery; **A.c.e.**, external carotid artery; **A.c.i.**, internal carotid artery; **A.p.**, pulmonal artery; **A.s.**, subclavian artery; **I–VI**, first-sixth aortic arch.

From each aortic arch three vessels originated in symmetrical arrangement: laterally, the A. subclavia; in the middle, the A. carotis externa; and medially, the A. carotis interna. In all other cases the aortic arch was apparently normal. In the cases of Power, Kosinki, Macalister, Fife and Boyd, the right side, and in all the other cases, the left side was affected. The cases of Malacarne, Kosinski, Gottschau, Angermayer, Fife and Boyd can be explained with persistence on the part of the dorsal arotic root between the junction with the third and fourth aortic arch and with obliteration of the part of the third aortic arch which normally develops into

the root of the internal carotid artery (see Fig. 5). This must lead on the right side to a separate origin of both carotid arteries from the innominate artery, on the left side from the aortic arch. In Fife's case the separate origin of the right external and internal carotid arteries from the aortic arch was combined with a right aortic arch and other anomalies.

In Smirnov and Schmeidel's cases the findings were more complicated, because a short distance above their origin the walls of the vessels were adherent to each other in a circumscribed area, but no communication between the lumina existed. Schmeidel assumes that again the root of the dorsal aorta between the fourth and third aortic arches had persisted. The third aortic arch, however, had also persisted for a longer period of time but had not grown in length together with the other parts of the embryo. In this way the external and internal carotid arteries were drawn closer to each other and eventually came into direct contact, being followed by obliteration of the lumen of the third aortic arch.

Unexplained remain Power and Macalister's cases in which the right subclavian artery formed the first, the external carotid the second, and the internal carotid artery the third branch, the left common carotid the fourth, and the left subclavian artery the fifth branch of the aortic arch. If the formation of the aortic arch had proceeded in a normal way persistence of the dorsal aorta between the fourth and third arch together with obliteration of the third arch on the right side would lead to the conditions described by Kosinski but not to separate origin of subclavia, external and internal carotid artery from the aortic arch.

4. Unusually Deep Division of the Common Carotid Artery. Two such cases were described by Kantor, one by Orr and another by Adachi. The division took place almost at the site of the origin of this vessel from the innominate artery or the aortic arch. Kantor assumes that either the part of the ventral aortic root between the fourth and third aortic arch had shown an impeded growth or that a spur had grown down-

ward secondarily between the two arteries towards the innominate artery or the aortic arch. Angermayer believes that in these cases, similarly to the above described cases, the dorsal aorta between the fourth and third arch had persisted and the third arch had been obliterated. In this way both carotid arteries have first originated separately from the innominate artery or the aorta but had later on approached each other and secondarily united. In favor of this assumption speak the relatively frequent cases in man in which only two branches (A. anonyma together with A. carotis comm. sin., and A. subclavia sin.) are given off from the aortic arch. In these cases unquestionably a secondary union of the anonyma with the A. car. comm. sin. had taken place. This is the rule in pigs; in ruminants, all three branches have become united into one big trunk due to shifts occurring during the growth period.

Cases in which the common carotid artery was shorter than normal but not so short as in the two cases just described, are not infrequent (Morgagni and others).

5. Anomalies in the Course of the Internal Carotid Artery. Marked tortuosity, as a rule at the level of the second cervical vertebra, is not particularly rare. Although this tortuosity has been found by Cairney four times among the 20 fetuses from the second half of fetal life, it is regarded by Adachi in the majority of cases as senile change.

In rare instances the internal carotid artery has been found medially and ventrally from the external carotid artery whereby branches of the external carotid ran over the ventrolateral surface of the internal carotid (Hyrtl, 1841; Yuhino and Shirota, Schreiber—two cases).

6. Abnormal Branches, Normally Given Off by the External Carotid Artery. A great variability prevails in the point of origin of the vessels normally given off by the external carotid artery. Sometimes some of them are given off by the external carotid artery and sometimes by the internal carotid artery. According to Krause the following branches have been found originating from the internal carotid artery: Aa.

laryngea superior, pharyngea ascendens, pharyngea ascendens accessoria, occipitalis, lingualis, transversa faciei. Hyrtl, 1841 mentions a case in which the Aa. auricularis posterior and occipitalis originated with a common trunk from the internal carotid artery. Adachi describes a case in which a thin arterial branch was given off from the posterior circumference of the common carotid artery, 1 cm. below the angle of bifurcation, went upward and opened into the internal carotid artery from behind, 1 cm. above the bifurcation.

The embryological explanation for this great variability might be that all these vessels originate from a capillary net-

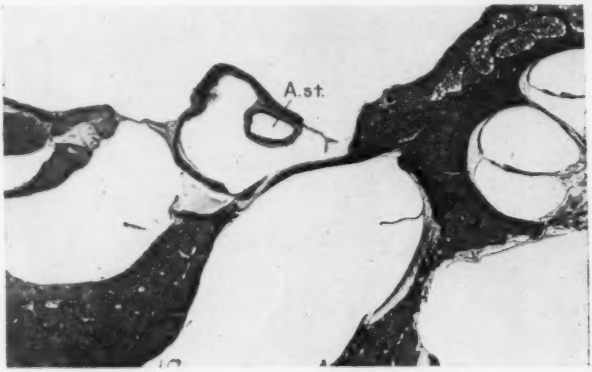

Fig. 6. Stapedial artery (**A.st.**) between the crura of the stapes.

work with which vascular buds from the neighboring arteries become connected. Certain parts of the network are utilized in the formation of the definite arteries. In some instances vascular buds are given off not by the external carotid artery but by the third aortic arch. Congdon's model, *e.g.*, of the arteries of a 14 mm. embryo shows on the left side near the point of origin of the external carotid artery three small vessels which are given off by the third aortic arch and which could very well have developed in such anomalous branches. It should furthermore be kept in mind that the external carotid artery undergoes in the course of its development a medio-

lateral shift which would also favor the development of anomalous vascular branches.

Anomalies of the Second Aortic Arch. All mammalia show a certain basic pattern in the arrangement of the arteries of the head. Among them the stapedial artery plays a very important rôle. This vessel persists completely in quite a number of animals and partially in others. When fully developed, it shows an upper branch which gives origin to the middle meningeal artery and anastomoses with the ophthalmic artery in the orbit and an inferior branch which develops in the internal maxillary artery.

In certain bats (vespertilio murinus) the main stem continues into the upper branch. The inferior branch has lost its connection with the main stem and has been taken over by the external carotid artery.

Exactly the same conditions have been found in the eight cases in which a persistent stapedial artery has been observed in man (see Fig. 4, C) (Hyrtl, 1836, 1845; Zuckerkandl, Alexander, Lewin, Brock, 2 cases; Adachi).

CASE REPORT.

Before discussing the findings of these authors, a new observation of persisting stapedial artery in man shall be reported.

A woman, aged 64, died of adenocarcinoma of the cecum. She had also suffered from osteitis deformans Paget, the principal lesion being found in the calvaria.

Examination of the right temporal bone in horizontal serial sections showed extensive involvement of the labyrinthine capsule by Paget's disease. The middle ear and mastoid were free from pathological changes.

An arterial vessel measuring about 2 mm. in diameter is seen penetrating the floor of the middle ear cavity and going along a bony ridge to the posterior part of the promontory. The origin of the artery is not contained in the sections, but in view of its closeness to the internal carotid artery in the lowest preserved sections, there can be hardly any doubt that it comes from this vessel. On the promontory, it became enclosed in a bony canal and runs upward and backward. Leaving the promontory, it goes upward between the crura of the stapes. It is covered on its outside with a thin layer of mucous membrane and is adherent to the posterior surface of the anterior crus of the stapes (see Fig. 6). Then it enters the facial canal through a dehiscence just behind the cochleariform process and extends a short distance forward together

with the facial nerve. Two mm. behind the geniculate ganglion, the artery leaves the facial canal through a special opening and proceeds between the dura and inner surface of the middle fossa, forward and upward. Before leaving the facial canal, the artery gives off two branches: One running forward together with the greater petrosal nerve; one backward and downward with the facial nerve. The latter vessel anastomoses with the stylomastoid branch of the posterior auricular artery. The intracranial ramification of the anomalous vessel is not contained in the sections.

The left temporal bone had not been examined.

COMMENT.

The course of the stapedial artery in all the reported cases was practically identical. In all of them, with three exceptions (Zuckerkandl, Brock, 1 case, Adachi), the artery was enclosed in an osseous canal of the promontory. This canal was interrupted in Lewin's case. The artery was sometimes found on one, in others on both sides.

In four cases (Hyrtl, 1845; Alexander; Brock, 2 cases) the origin from the internal carotid artery was proven; in the case here reported, it was very probable; in three cases of Zuckerkandl, Lewin and Adachi, its origin was undecided. In Hyrtl's first case an origin from the internal maxillary artery was assumed. This, however, seems to me very doubtful, because it contradicts all embryological and comparative anatomical evidence.

The absence of other anomalies of the ramification of the internal maxillary artery in Hyrtl's case indicates that the anastomosis between the external carotid and stapedial artery had taken place at the usual place, beyond the stapes and middle ear. In order to penetrate the floor of the tympanic cavity and to go upward between the crura of the stapes, it would have been necessary that the anastomosis joined the root of the stapedial artery between the internal carotid and stapes. If this had actually been the case, the main stem of the stapedial artery, after giving off the middle meningeal artery, had continued forward through the Glaserian fissure into the infraorbital and mandibular branches.

In none of the mammalia does the stapedial artery originate from the internal maxillary artery. Only once is such

a condition suspected by Hyrtl, 1854 (Orycteropus capensis), but the author states expressly that the head was in a very poor state of preservation and a definite opinion was impossible.

In certain animals, such as squirrels and marmots, the tympanic part of the stapedial artery as well as the anastomosis between stapedial and external carotid artery are present. Here again, the anastomosis connects with the distal part of the stapedial artery beyond the stapes and middle ear cavity.

The intracranial ramification of the anomalous artery was studied by Alexander and Adachi.

In Alexander's case the vessel divided itself into a medial branch which supplied the inner surface of the greater wing of the sphenoid and anastomosed with the orbital vessels and a lateral branch which substituted the missing meningeal artery. In Adachi's case the anastomosis with the orbital vessels was very wide, otherwise the ramification was the same.

Anastomoses between the ophthalmic artery and the middle meningeal artery are always present in man but are very narrow. Sometimes, however, the ophthalmic artery is partially or completely given off by the middle meningeal or, contrariwise, the anterior branch or both branches of the middle meningeal come from the ophthalmic artery, and in these cases the foramen spinosum is missing.

The embryological explanation of the cases of persistent stapedial artery in man seems to be persistence of the conditions found by Fisher in an embryo of 20 mm. (see Fig 4, C). These findings, together with the aforementioned anomalies of the middle meningeal artery, support the opinion that the extracranial part of the middle meningeal artery is a secondary formation which under certain conditions fails to develop.

In this connection must be mentioned the small artery which is regularly present in the stapedial region (Hyrtl, 1845; Zuckerkandl and Adachi). According to Altmann, this artery originates from the superficial petrosal branch of the middle meningeal artery, accompanies the facial nerve down-

ward, anastomoses with the stylomastoid branch of the posterior auricular artery and passes downward through a dehiscence in the inferior wall of the facial canal. It is then located in the free margin of a semilunar fold which runs from the posterior wall of the niche of the oval window, forward and laterally. While in this fold, the artery passes through the crura of the stapes and runs to the arterial plexus on the surface of the promontory. According to its origin and course, this vessel most probably represents a rudiment of the middle part of the main stem of the stapedial artery between the stapes and point of origin of the supraorbital branch (see Fig. 4, D).

ANOMALIES OF THE FIRST AORTIC ARCH.

No arterial anomalies have been reported in which the persistence *in toto* or in part of the first aortic arch or of the earlier or later mandibular arteries has been assumed; however, I found one case reported by Smirnov which could possibly be interpreted in this way. Unfortunately, this observation is known to me only from an abstract in the *Anatomischer Bericht.*

In a newborn child the left external and internal carotid arteries originated separately from the aortic arch. A deep terminal branch of the external carotid artery passed, together with the internal carotid artery, through the carotid canal. It opened into the internal carotid artery at the base of the brain a short distance distal from the point where the ophthalmic artery was given off.

As previously mentioned, the external carotid artery, when growing cranially, probably links with the endothelial channels of the subpharyngeal plexus left by the retrogression of the first and second branchial arch arteries. It is conceivable that if the dorsal part of the first aortic arch or of the earlier or later mandibular arteries persist, a branch of the external carotid artery should go into the internal carotid artery.

One would expect this union to take place cranially from

the middle ear because the first aortic arch runs over the cranial surface of the first pouch from which the middle ear is derived. It should, on the other hand, lie proximal to the point of origin of the ophthalmic artery, because this vessel is given off from the part of the internal carotid artery which extends beyond the first arch; however, I think that the fact that it was given off in Smirnov's case immediately distal from the ophthalmic artery is not of decisive importance. In Congdon's model of an embryo with 22 somites, two separate vessels originate approximately from the point where the first aortic arch goes over into the dorsal aorta (see Fig. 2). One of them goes to the optic vesicle and one to the cerebral venous plexus.

In somewhat older embryos the primitive internal carotid artery has already been formed and both branches come off from the latter. Shifts in the origin of vessels due to growth factors during embryonic developement are, as already mentioned, quite common.

Wax plate models and sagittal reconstructions of young embryos show that a presegmental dorsal artery accompanying the first branch of the Vth nerve would be situated at about the same level as the dorsal root of the first aortic arch. If this presegmental dorsal artery persists, it opens in the adult into the carotis in the cavernous sinus, not far away from the place where the vessel in Smirnov's case joined the carotid artery. All the mentioned evidence makes it conceivable that the vessel in question actually represents a remnant of the first aortic arch.

Krause mentions that in rare instances the upper end of the ascending pharyngeal artery enters the carotid canal together with the internal carotid artery and supplies the dura mater beside the sella turcica or the wall of the cavernous sinus but does not mention any communications between the two vessels. It remains an open question whether this condition has also something to do with persistence of certain parts of the first aortic arch system.

ANOMALIES DUE TO PERSISTENCE OF PRESEGMENTAL AND SEGMENTAL DORSAL BRANCHES.

1 Persistence of the Vessel Accompanying the First Branch of the Vth Nerve (see Fig. 7). This is a typical anomaly which in the adult has been described in a number of cases (Quain, Tüngel, Duret, Tareniecky, Hochstetter, 2 cases, Flesch, Decker, Kundrat, 2 cases, mentioned by Hofmann,

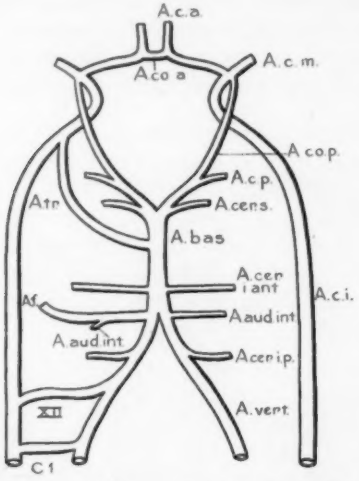

Fig. 7. Diagram showing the anomalous branches of the basilar and vertebral arteries. **A.aud.int.**, internal auditory artery; **A.bas.**, basilar artery; **A.c.a.**, anterior cerebral artery; **A.ci.**, internal carotid artery; **A.c.m.**, middle cerebral artery; **A.c.p.**, posterior cerebral artery; **A.cer.i.ant.**, inferior anterior cerebellar artery; **A.cer.i.p.**, inferior posterior cerebellar artery; **A.cer.s.**, superior cerebellar artery; **A.co.a.**, anterior communicant artery; **A.co.p.**, posterior communicant artery; **A.f.**, acousticofacial artery; **A.tr.**, trigeminal artery; **A.vert.**, vertebral artery; **c1**, first cervical artery; **XII**, hypoglossal artery.

Blackburn, Oertel, Okrös, Feller, Hasenjäger, Slany, Sunderland). It is represented by an anastomotic vessel (see Fig. 7) which leaves the basilar artery approximately in the middle of its course between the A. cerebelli superior and the A. cerebelli inferior anterior and goes either along the lateral aspect of the dorsum sellae or through the lateral part of the dorsum itself into the cavernous sinus, where it opens into the

internal carotid artery. The condition is usually associated with anomalies in the circle of Willis and differences in the caliber of the vertebral arteries.

A similar malformation was seen by Hochstetter in an embryo of 46.6 mm., and by Rigot in a horse.

2. Persistence of the Vessel Accompanying the Acousticofacial Nerve (see Fig. 7). The writer described a vessel in a seven months' fetus which originated from the basilar artery between aa. cerebelli inferior anterior and posterior, and went into the internal auditory meatus of the right side. After giving off the internal auditory artery, it passed into

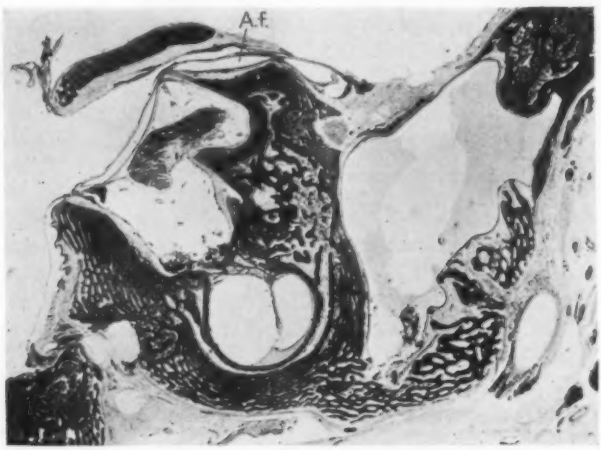

Fig. 8. Acousticofacial artery (**A.f.**), piercing the roof of the internal auditory meatus (after Altmann: Ztschr. f. Anat. u. Entw. Gesch., 97:509, 1932).

a separate canal through the upper wall of the internal auditory meatus and ran between the bone and the dura mater laterally (see Fig. 8), then divided itself into an anterior and posterior branch which supplied the area normally served by the middle meningeal artery. The latter as well as the foramen spinosum was absent.

In this case it was assumed that a presegmental artery accompanying the acousticofacial nerve, with the exception of its ventral terminal part, had persisted and become connected with the superior branch of the stapedial artery (see Fig. 9). The stem of the stapedial artery up to the point of junction with the anastomosis from the external carotid artery had atrophied, and the secondary connection between the intracranial part of the middle meningeal artery and the internal maxillary artery failed to develop. Finally, the middle meningeal artery came from the basilar artery, and the infraorbital and inferior alveolar arteries from the internal maxillary artery.

It might be of interest to mention that Hyrtl, in 1858, saw in certain fishes (eagle rays—Myliobatis Narinari) a connection between the internal auditory artery and a branch of the external carotid artery which perforates the cartilage of the skull and shows the same ramification on the outer surface of the dura as the middle meningeal artery.

3. Persistence of One of the Vessels Accompanying the Hypoglossal Nerve (Hypoglossal Artery) (see Fig. 7). This condition has been observed three times (Batujeff, Hirakô, Oertel). In Oertel's case it was combined with a persistent trigeminal artery. In all three cases the vessel originated from the internal carotid artery shortly before the latter entered the carotid canal. It passed together with the hypoglossal nerve through the hypoglossal canal into the skull and ran forward at the base of the brain as the basilar artery. The vertebral artery of the same side was normal in Oertel's case, rudimentary in that of Batujeff, and missing in that of Hirakô. The vertebral artery of the other side was normal in Hirakô's case, very thin in those of Oertel and Batujeff. In the latter case it did not join the basilar artery. Hofmann mentions the fact that in ruminants an artery enters the skull through the foramen hypoglossi, gives off branches to the meninges and sends a large branch to the basilar artery.

4. Persistence of the First Cervical (Postoccipital) Artery (see Fig. 7). In Gotschau's case with separate origin of the

left external and internal carotid arteries from the aortic arch, the internal carotid artery, 12 cm. above its origin, gave off what the author calls a superior vertebral artery. This vessel went over the deep muscles of the neck to the atlas and entered the cranial cavity between the atlas and occiput. He also describes an inferior vertebral artery which orginated at the usual place of origin of the vertebral artery, but was very small and could be followed upward only to the level of the fourth vertebra. It was situated lateral to the

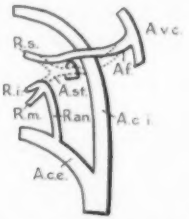

Fig. 9. Diagram explaining the development of the acousticofacial artery. **A.c.e.,** external carotid artery; **A.c.i.,** internal carotid artery; **A.f.,** acousticofacial artery; **A.st.,** stapedial artery; **R.an.,** anastomotic branch between external carotid and stapedial artery; **R.i.,** infraorbital branch of the stapedial artery; **R.m.,** mandibular branch of the stapedial artery; **R.s.,** supraorbital branch of the stapedial artery.

foramina transversaria. According to Kemmetmüller, this latter artery was most probably not a true vertebral artery but an ascending cervical artery.

SUMMARY AND CONCLUSIONS.

Almost all the malformations of the internal carotid artery and its branches can be explained as deviations from the normal development. Many of them represent conditions which are regularly present in other mammals or in lower vertebrates.

From an embryological point of view the anomalies can be divided into two main groups. The first one comprises cases involving the first four aortic arches and the dorsal aorta, the second group, anomalies in the retrogression of the segmental and presegmental dorsal arteries.

Anomalies of the fourth and third arches and the dorsal aorta produce hypoplasia or complete absence of the internal carotid artery, separate origin of the external and internal carotid artery from the aortic arch or the innominate artery; unusually deep division of the common carotid artery, anomalies in the course of the internal carotid artery, and origin of abnormal branches from the internal carotid artery which are normally given off from the external carotid artery.

In the region of the second arch, persistence of the later hyoid artery leads to a persistent stapedial artery. This vessel is regularly found in many species of mammals but is very rare in man. A new case is reported in which the abnormal vessel originated from the internal carotid artery, went through the floor of the tympanic cavity, ran, enclosed in a bony canal, over the promontory, between the crura of the stapes and left the middle ear through a dehiscence in the inferior wall of the facial canal. It then went forward with the facial nerve but left the canal soon and ramified on the outer surface of the dura of the middle fossa. The infraorbital and alveolar arteries were given off in all the reported cases from the internal maxillary artery.

Persistence of parts of the first aortic arch system may lead to the formation of abnormal communications between branches of the external and the intracranial part of the internal carotid artery. In this way the findings were interpreted in a case in which a deep branch of the external carotid artery joined the internal carotid artery, passed together with the latter through the carotid canal and the cavernous sinus and opened into the internal carotid immediately after the latter had given off the ophthalmic artery.

Persistence of the presegmental dorsal artery which accompanies the first branch of the Vth nerve leads to the formation of an anastomosis between the middle part of the basilar artery and the internal carotid artery in the cavernous sinus.

Persistence of the artery accompanying the acousticofacial nerve with formation of a connection between this vessel and the supraorbital branch of the stapedial artery had led in one case to the formation of an artery which originated from the

middle part of the basilar artery, entered the internal auditory meatus, perforated its roof, entered the middle fossa and replaced the missing middle meningeal artery.

Peristence of the hypoglossal or the first cervical artery causes the origin of the vertebral artery from the internal carotid artery near the base of the skull. The vessel enters the cranial cavity through the hypoglossal canal or over the arch of the atlas between the latter and the occiput. The cervical part of the vertebral artery may be hypoplastic or absent.

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SUMMER COURSE IN AUDIOMETRY AND FITTING OF HEARING AIDS.

During the 1947 Summer Session the Departments of Speech, Psychology and Otolaryngology of the State University of Iowa are again offering an intensive four weeks' course in Audiometry and the Fitting of Hearing Aids. The course will run from June 23 to July 19 and is open to anyone meeting college entrance requirements.

A series of week-end lectures and round table discussions on various aspects of hearing conservation will be featured as a part of the summer program. Mrs. Spencer Tracy, Director of the John Tracy Clinic, Los Angeles; Dr. Helen Lane, Principal, Central Institute for the Deaf, St. Louis; Dr. Werner Mueller, Associate in Otolaryngology, Massachusetts Eye and Ear Infirmary, Boston, and Harvard Medical School; and Dr. Martin F. Palmer, Director of the Institute of Logopedics, the Municipal University of Wichita, Kan., will be the speakers.

Inquiries may be address to Jacqueline Keaster, Assistant Professor, Speech and Otology, the Speech Clinic, State University of Iowa, Iowa City, Iowa.

SURGERY OF THE FRONTAL SINUS.*†

HENRY M. GOODYEAR, M.D.,
Cincinnati, Ohio.

Frontal sinuses are not present at birth and do not usually give the rhinologist concern before eight to 12 years of age; however, near 12 years of age one most frequently sees acute fulminating infections of the frontal sinus following swimming. Typically, within 12 to 24 hours following swimming there occurs acute pain upon palpation, and swelling and edema about the eye, often closing the lids. The nose may be swollen, and no secretion can be detected coming from the frontal sinus. The nasofrontal duct is closed; the pressure of fluid within the frontal sinus increases, the temperature rises, and a chill or chilly sensation may occur.

What is the most helpful procedure in these cases? Penicillin and sulfadiazine are indicated whether the treatment be surgical or expectant. One school may advocate rest in bed, cold compresses, Roentgen ray treatment, chemotherapy and no surgery unless complications occur. Courville[1] states that subdural empyemas are four times as frequent in these primary acute cases as in acute attacks in chronic frontal sinus infections, death sometimes occurring within three or four days.

I believe fewer complications are likely and immediate relief of pain is secured by trephining the floor of the frontal sinus; however, this procedure must be guarded in its extent. Even the unnecessary elevation of the periosteum will cause a periostitis.

First, a Roentgenogram is necessary before attempting any surgery upon the frontal sinus. One or both frontal sinuses may be absent in 16 per cent of adults.

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*Read at the meeting of the Southern Section, American Laryngological, Rhinological and Otological Society, Inc., Miami, Fla., Jan. 6, 1947.

†From the Department of Otolaryngology, College of Medicine, University of Cincinnati.

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A curved incision should be made just below the eyebrow and curved downward on a line midway between the inner canthus and the midline of the nose. A half-inch incision usually suffices, made under local anesthesia or sodium pentothal where general narcosis is desired.

The periosteum is incised but *not elevated*, and the opening in the bone is made with a nail trephine as is used in relieving the accumulation of blood under pressure under the finger nail. You who have experienced such an injury to a finger know what a humane relief of pain trephining will give. The relief of pain in the frontal sinus is equally gratifying. A few half-turns of the trephine and the thin, noncancellous bone of the frontal sinus is penetrated and drilling continued to the desired size opening. There is a welling of pus or serous fluid under pressure. The cavity may be irrigated by means of a 10 cc. syringe and a large, blunt needle or cannula with warm saline solution plus penicillin if desired. A few folded strands of silkworm-gut may be used as a drain. Within 48 hours the drain can usually be removed, and the wound closes as the nasofrontal duct becomes patent. Rarely do complications occur.

J. M. Brown[2] has strongly advocated early trephining.

If pus is found coming from the anterior middle meatus, usually trephining can be avoided or delayed.

It is important that the periosteum not be elevated following the primary incision through the soft tissues and the periosteum. Where periosteum is elevated, periostitis occurs and the danger of ostitis is greatly increased.

The point of the nail drill is placed in the periosteal incision, almost at a right angle (see Fig. 1) to the sagittal plane of the nose, medial to the suprafrontal notch and just posterior to the medial orbital ridge (see Fig. 2). Trephining in this area is through thin bone and not in a direction toward the posterior frontal sinus plate (see Fig. 3).

Eighteen years ago I recommended the use of the nail trephine for making the primary opening in the canine fossa in

a Caldwell-Luc operation to avoid the discomfort caused by tapping a gouge. The use of this instrument is even more gratifying in trephining the frontal sinus.

I have spoken only of the acute fulminating frontal sinus with intolerable pain, swelling and edema about the eye, and now I should like to mention the acute frontal sinus most often seen in adults, occcurring with each attack of what the patient considers a "cold" in the head, followed by severe

Fig. 1. Position of nail drill almost at right angle to the sagittal plane.

pain developing between nine and 12 in the morning. Early in my practice I watched these patients suffer through prolonged painful attacks.

In the past 10 years I have had the courage and experience of operating on these patients for relief of pain. In my cases the acute rhinitis has been of four to 10 days' duration; never have I operated intranasally in the first few days of the infection when trephining might have been preferred. Where the nasal space permitted, the anterior ethmoid cells were opened with a Myles nasal punch forceps, followed by a Pratt ring curette which was brought forward, breaking down any anterior ethmoid cells about the ostium of the frontal sinus. Thus

the curette entered the frontal sinus. There was a drainage of pus and relief of pain with no complications following.

If carefully done, there is no wide area of trauma in making this opening into the frontal sinus, and I believe the operation possesses less danger than a prolonged pent-up sinus infection.

Fig. 2. Nail drill enters just posterior to the medial orbital ridge.

I wish now to speak of surgery in chronic frontal sinus infections. If a lateral Roentgenogram shows ample width at the base of the frontal to permit the entrance of a Pratt curette, an intranasal surgical approach should be tried first before any external operation. Through the anterior ethmoid cells is the normal approach to the frontal sinus, and in most cases the intranasal approach will succeed.

Technique: The septum is corrected if necessary and a cystic middle turbinate may be split in the midline with a No. 15 Bard Parker knife and its lateral half bitten away. The eth-

moid cells are then removed or opened with a Myles nasal punch forceps (see Fig. 4), followed by a downward and upward biting sphenoid punch forceps (see Fig. 5). After

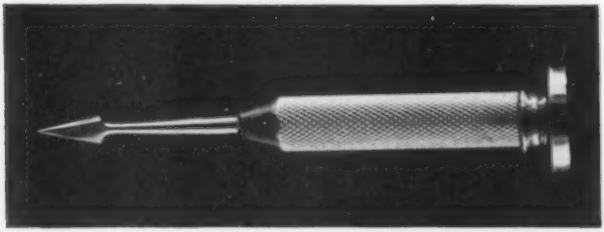

Fig. 3. Type of nail drill recommended. (Furnished by Max Wocher & Co., Cincinnati, Ohio.)

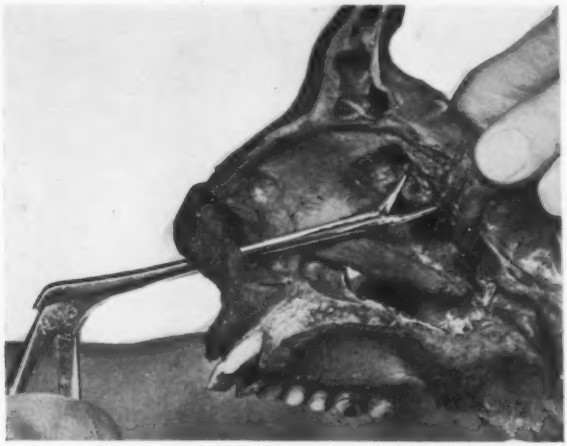

Fig. 4. Middle turbinate elevated showing a Myles nasal punch forceps entering the ethmoid cells.

entering the frontal sinus by means of a Pratt currette (see Fig. 6), this instrument may be pressed backward and downward to break away any thin bone protruding forward into the nasofrontal opening (see Fig. 7).

A rasp with a fairly sharp curve or a similarly shaped

sound may aid in *locating* the frontal ostium, but care must be taken not to rasp or attempt to remove any bone or tissue anteriorly.

If the mucous membrane has been carefully preserved and the opening freely admits a Pratt curette, it will remain patent. I have observed some of my cases after 20 years and

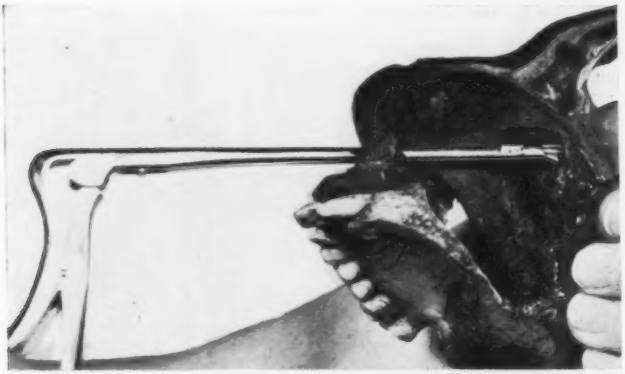

Fig. 5. Punch forceps (sphenoid type) removing posterior ethmoid cells. (Upward biting, used anteriorly.)

found the nasofrontal opening excellent where the aforesaid described procedure had been followed. Through the anterior ethmoid cells is the proper and natural approach to the frontal sinuses and the success and ease of the operation will depend on the ample size of these cells and the depth of the frontal sinus. The depth and width shown by Roentgenogram (see Fig. 8) are important in deciding upon an intranasal approach.

It is chiefly in those cases where the intranasal approach to the frontal sinus has failed, often due to a narrow base of the frontal sinus, that an external operation becomes necessary.

The Jansen-Lynch operation *per se* is excellent and not deforming, but has one unredeeming feature: the closing of

the nasofrontal opening in many cases by contracting fibrous tissue. I believe this feature could be largely eliminated by the use of the Ingals[3] self-retaining gold tube (see Fig. 9), which can be used as a routine procedure without fear of irritation or complications.

Recently, Goodale[4] and Weille[5] have reported that this problem can be solved by the use of a sheet or tube of tanta-

Fig. 6. Pratt curette (45° angle) in frontal sinus.

lum; however, I feel that the gold tube is simple and more practical than a sheet of metal. I think that a tantalum tube patterned after Ingals' tube would be satisfactory, as would that of acrylic resin[6] or vitallium.[7] There is no hesitation in using gold in repairing teeth. Why should we hesitate to use gold in so protected an area as that of the ethmoid frontal? Artificial eyes are now being fixed by means of tantalum sutures of the eye muscles immediately following enucleation.[8]

Anthony,[9] who has been a strong advocate of the Ingals tube reports having observed a tube in place for more than 18 years without any disturbance to the patient and the tube can still be probed with ease.

Dr. Kenneth Phelps[10] has observed a gold tracheotomy tube in place (without removal) for more than 10 years without ever showing any signs of metal irritation.

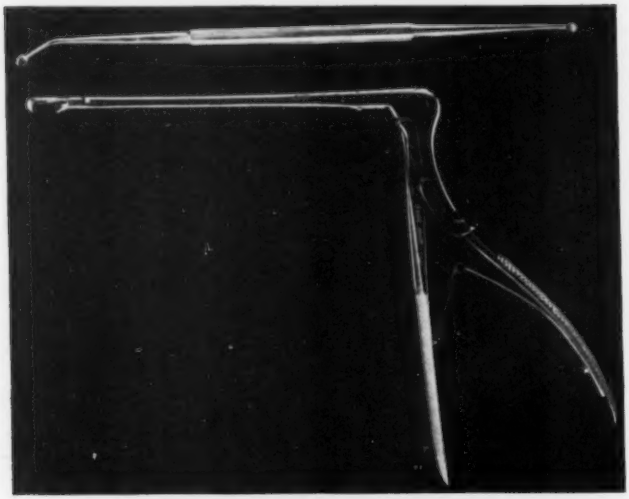

Fig. 7. Pratt curette and punch forceps, both downward biting as shown and upward biting are used.

No doubt we have all at some time used a rubber tube in the nasofrontal opening. I have kept the tube in place for more than six months, yet the passage was found closed 18 months after its removal. Hajek taught that three to six months' time was required for healing of the nasofrontal opening.

I believe the gold tube can be used to advantage in all radical external frontal sinus surgery, except where complete

obliteration is desired, and should be left in place for the life of the patient.

If obliteration is desired in secondary frontal sinus surgery, I would like to emphasize a few suggestions which I have observed to be most important and helpful.

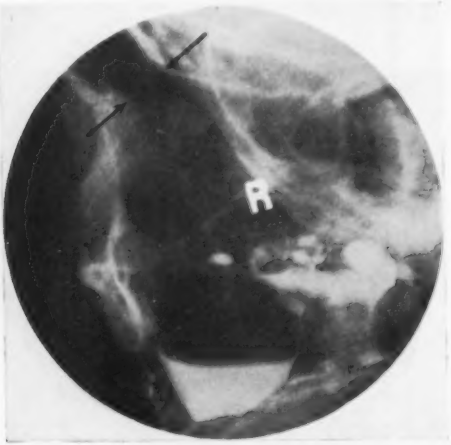

Fig. 8. Lateral view showing width and depth of the frontal sinus sufficient for surgical approach intranasally.

Fig. 9. Ingals gold tube. Split sections extend upward into sinus and are spread to retain tube in position. (Furnished by V. Mueller & Co., Chicago, Ill.)

If a Jansen-Lynch operation has been performed and the floor of the frontal sinus completely removed, the upward extension of the soft tissues of the orbit have usually well obliterated the lower portion of the frontal sinus.

I make an incision just above the eyebrow and elevate the

soft tissues over the entire sinus cavity. A trephine opening is then made with a Hudson perforator and the anterior bony wall is completely removed and beveled (see Fig. 10). All mucous membrane is removed, and the wound is completely closed with interrupted silk sutures. Now comes a very

Fig. 10. Incision above eyebrow, edges of sinus beveled.

important and often neglected procedure *as important as the operation itself:* small pieces of cotton or gauze soaked in tincture of merthiolate are continually piled and packed against the skin, forcing it deep under the orbital bridge (see Fig. 11) and precisely against the interfrontal septum which is often adjacent to the frontal ostium. With the packing piled

high, a firm bandage is meticulously placed so that the lower edge barely covers the sutures. Strips of adhesive are carefully placed to reinforce the bandage so that its position will be firm and unchanged and wholly undisturbed for two full weeks.

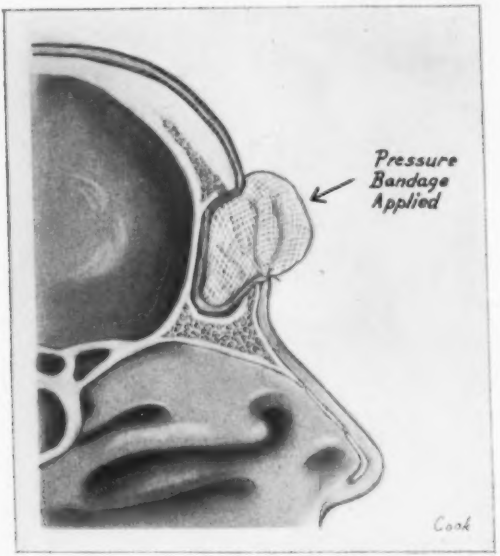

Fig. 11. Skin incision closed and packed firmly into sinus cavity.

At the end of three or four days, the lower edge of the bandage is raised only slightly; sufficient to remove the silk sutures.

At the end of two weeks the primary bandage is removed, at which time the skin and soft tissue have adhered firmly to the posterior wall.

My oldest case is one done by this method 20 years ago, after 18 operations for a recurring frontal sinus infection. Today the deformity is not extreme, since the orbital arch

and eyebrow are well preserved and the edge of the bony opening carefully beveled.

Should the bandage become loose or move in the first four to seven days, the entire operation may fail unless the external packing and bandage are immediately replaced and retained for another two weeks.

Osteomas of the frontal ethmoid area are always accompanied by a chronic suppuration of the frontal sinus where clinical symptoms occur and require an external operation.

Mucoceles of the ethmoid and frontal region in a very large majority of cases can be approached by the intranasal route.[11] The mucocele usually has extended well down into the anterior ethmoid region (see Fig. 12) and any tumor mass showing in the orbit or over the forehead is pressed back by means of the finger into normal position. No external incision is necessary. Only in cases where extensive ossification in the ethmoid region has occurred, rather than the usual cystic thinning of bone, is an external operation indicated.

SUMMARY.

I have emphasized the importance of early trephining in acute frontal sinuses, and have presented an instrument to simplify this procedure, and have emphasized the direction of attack away from the posterior plate of the frontal sinus.

Intranasal drainage of the frontal sinuses is advocated in selected acute recurring cases.

The technique of the intranasal frontal sinus operation is stressed.

The use of the gold tube in external frontal sinus surgery is recommended.

The importance of a modified Killian procedure for obliteration of the frontal sinus is presented in detail.

The Jansen-Lynch operation with the use of the gold tube is advised in all osteomas of the ethmoid-frontal area with suppuration.

A simple intranasal operation is advocated in cases of ethmoid and frontal mucoceles.

Fig. 12. Relative extension of mucocele downward into the ethmoid area. Instrument for cutting opening into the base of the mucocele.

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556 Doctors' Building.

MISSISSIPPI VALLEY MEDICAL SOCIETY MEETS AT BURLINGTON, IOWA, NEXT OCT. 1-2-3.

The Twelfth Annual Meeting of the Mississippi Valley Medical Society will be held in the Municipal Auditorium at Burlington, Iowa, Oct. 1, 2, 3, 1947, under the presidency of W. A. Sternberg, M.D., F.A.C.S., of Mt. Pleasant, Iowa, a trustee of the Iowa State Medical Society.

At the November meeting of the board of directors the following officers were elected: President-elect, W. O. Thompson, M.D., F.A.C.P., Chicago, Ill.; first vice-president, B. J. Dierker, M.D., F.A.C.S., Ft. Madison, Iowa; second vice-president, J. F. Ross, M.D., F.A.C.S., Golden, Ill.; third vice-president, D. L. Sexton, M.D., F.A.C.P., St. Louis, Mo; secretary-treasurer, Harold Swanberg, M.D., F.A.C.P., Quincy, Ill.; accounting officer, Ralph McReynolds, M.D., F.A.C.P., Quincy, Ill. The executive committee which will have charge of the Burlington meeting comprises Dr. W. A. Sternberg, Dr. W. O. Thompson, Dr. D. L. Sexton, Dr. Harold Swanberg and Dr. J. C. McKitterick.

THE USE OF 2.5 PER CENT SULFATHIAZOLE IN PROPYLENE GLYCOL FOR RESPIRATORY INFECTIONS.*

BRADFORD N. CRAVER, M.D., and
FREDRICK F. YONKMAN, M.D.,
Summit, N. J.

The efficacy for infections of the nose and throat of a 3 per cent solution of sulfathiazole in propylene glycol, topically applied with an atomizer, was initially reported by us in 1942.[1] The purpose of this paper is twofold: *1.* to give information about the preparation of the solution; *2.* to report the results obtained in a limited number of trials of the preparation in various upper respiratory infections in patients.

The sulfathiazole should be added to the propylene glycol in a dark bottle and solution effected by heating the bottle with its contents in a hot water bath. A 2.5 per cent solution is preferable, because at room temperature that has never shown the tendency to crystallize that the 3 per cent solution occasionally showed. The dark bottle protects the preparation from light, which in time causes the colorless solution to become yellow or brown. This darkening of the solution should in any case cause no concern, for we found it did not measurably diminish the potency of the preparation nor augment its toxicity. Sulfathiazole is better than sulfanilamide because of its activity against a greater number of organisms. Sulfadiazine or sulfamerazine would probably be more desirable, but, unfortunately, they are only slightly soluble in propylene glycol.

The toxicity, acute and chronic, of propylene glycol has been so thoroughly studied and fully reported in recent years[2-5] that it would be purposeless to repeat it. The correctness of the suggestion by Seidenfeld and Hanzlik,[2] in

*From Wayne University College of Medicine, Detroit, Mich.
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1931, that propylene glycol might prove a valuable vehicle for certain pharmaceuticals has been confirmed by the number of preparations now available which employ propylene glycol as the vehicle. The toxicity of propylene glycol is so low that the amount administered by an atomizer can be disregarded. The objection has been raised that the amounts of sulfa drug in this preparation even though small might lead to sensitization. In the several score patients who have tried this therapeutic agent no evidence of a reaction or of sensitization has been seen. That is not proof it will not occur, but is merely evidence that thus far it hasn't, perhaps because of the minute amounts of sulfathiazole administered by an atomizer. The value of the sulfathiazole in the preparation could be determined only by a careful and extended study. We contemplated such a study, but during the war years other demands prevented it and at present the necessary clinical facilities are not readily available to us. This material has been employed by a considerable number of our former colleagues and medical students, as well as upon patients coming under their care. The results were so promising as to commend a thorough, critical study of this therapeutic agent. Accordingly, our own rather informal experiences are here summarized in the hope that others with the necessary clinical facilities may be persuaded to undertake such a study. The preparation was most effective in treating the dry and irritated throat which frequently precedes the development of a frank "head cold." The relief was often so prompt as to suggest a significant local anesthetic effect from the propylene glycol, not surprising in view of its structure. It was of little value for the acute stage of the cold itself, but it was of greatest value in treating the secondary bacterial complications which may follow a cold or, in keeping with the hypothesis of Brown,[10] usher in a cold. We have at hand one dozen written reports by former students describing their own as well as patients' experiences with sulfathiazole in propylene glycol. Several of the reports describe the use of the drug on more than one occasion. Many of these same students have not been without the drug since. One report states the drug revealed no value, but the majority are

unqualifiedly enthusiastic in describing its effectiveness, especially when employed semiprophylactically to treat the first symptoms of a sore throat.

Blackford[11] reported several cases in which this preparation was of definite value, as he believed, in controlling or preventing infections in wounds. He recommends a study of its effect on ciliary activity before its employment in upper respiratory infections. It inhibits ciliary activity presumably because of marked hypertonicity. Since the acute infection also inhibits ciliary activity, this objection would not appear to be an adequate reason for discarding the solution.

Callomon,[12] in his painstaking study of the effects of propylene glycol, and various drugs dissolved therein, upon the nasal mucous membranes of mice, reached the following conclusions: *1.* The propylene glycol alone was as innocuous as an isotonic solution of sodium chloride; *2.* the 3 per cent solution of sulfathiazole in propylene glycol was the least irritating of all the solutions employed.

Blackford and Robb,[13] who have employed this preparation for several years, have reported on the basis of their critical studies that they found the preparation of particular value in the treatment of chronic atrophic catarrh, ozena and persistent vestibulitis.

The drug has been used successfully in treating several cases of bacterial conjunctivitis in patients. Its initial application causes sharp but fleeting stinging, probably due to hypertonicity. This possible application of the drug is also worthy of a careful and extended study. A final judgment as to its usefulness must await a much more critical evaluation than our lack of time and facilities has permitted us to give it, and it is our hope that this problem may soon be given serious attention by interested clinicians.

Summary: The method of preparing 2.5 per cent sulfathiazole in propylene glycol has been described and evidence has been presented suggesting its value in treating upper

respiratory infections. The evidence warrants an extended study of the potential usefulness of this preparation.

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A HEARING AID FOR THE RELIEF OF TINNITUS AURIUM.*

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For practical purposes tinnitus aurium may be classified into two kinds: the transient and the lasting. Head noises due to impacted cerumen, blockage of the Eustachian tube, acute otitis media and toxicity from salicylates, alcohol or ergot, are most often transient in character. In this group the etiology is evident, and the therapeutic approach has a sound logical basis. On the other hand, head noises complained of by the neurasthenic individual are usually of long duration and baffle the ingenuity of the attending otologist. Considerable diagnostic and therapeutic difficuties are encountered in tinnitus aurium of the arteriosclerotic, allergic and endocrine patients. In the treatment of this group, one must enlist the aid of the internist, endocrinologist and allergist.

The objective type of tinnitus is encountered in aneurysm of the internal carotid or basilar artery, dehiscence of the floor of the tympanic cavity with protrusion of the jugular bulb, and in abnormal action of muscles of the pharynx. Here, the head noises can be heard by the examiner through a stethoscope on the side of the neck or on the skull, and the treatment available in some of these cases is surgical. In intracranial growths, tinnitus is frequently a most distressing symptom; however, soon after a cerebral neoplasm is diagnosed, it leaves the province of the otologist and enters that of the neurosurgeon.

Most patients who suffer of tinnitus aurium associated with deafness are otologic problems. Depending upon the etiology, both symptoms are sometimes relieved by one therapeutic procedure. A polyp in the middle ear and a benign

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tumor of the nasopharynx will yield to surgery readily, while a radiosensitive malignant growth may be kept in check by radium or X-ray. In otosclerosis, the fenestration operation will restore hearing and afford relief from tinnitus in a large percentage of the cases. A few of these individuals had such distressing head noises that operation of severing the auditory nerve was contemplated, but miraculous relief followed the fenestration operation. Clearly, all that this surgical procedure can accomplish is to make a path for extraceptive sound to reach the inner ear and by doing so, the patient's intrinsic tinnitus is either subdued or becomes tolerable.

The benefits obtained from a hearing aid are analogous to those of the fenestration operation. By amplification, much outside sound is enabled to reach the cochlea, crowding out and masking the patient's head noises. As a matter of fact, it was in the routine fitting of hearing aids that we discovered the therapeutic advantages of this mechanical means in regard to tinnitus aurium. We found it most efficacious in otosclerosis, for those patients who are not suitable or are unwilling to undergo the fenestration operation. In nerve deafness, if no extraordinary tolerance difficulties are present, a hearing aid will afford considerable relief from head noises simultaneously with improvement in hearing. Chronic adhesive otitis media is sometimes associated with most distressing tinnitus. Here again, a hearing aid is frequently most helpful.

Representative cases are here presented.

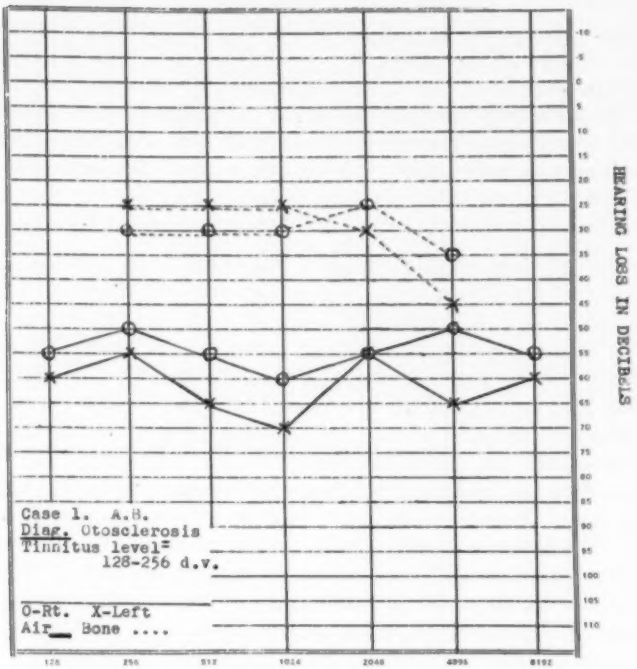

Fig. 1. Hearing loss in decibels.

Case 1: Mrs. A. B., aged 42, deafness progressive, dating back to the time of puberty, complained of tinnitus aurium in both ears, worse in the left. By measurement, the head noises were found to be at the level of 128-256 d.v. There is no history of any trouble referable to the ear, nose and throat, and an examination of the upper air passages disclosed no abnormality. The pharyngeal Eustachian orifices were normal on inspection with the nasopharyngoscope, and were patent on catheterization. Rinne is negative and the loudness balance test shows no recruitment.

A hearing aid with "flat" amplification to the left ear gave the patient relief from her tinnitus.

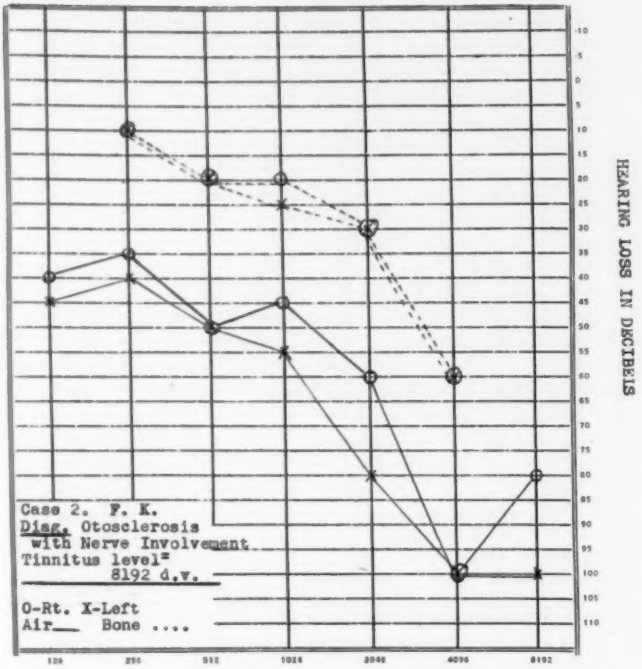

Fig. 2. Hearing loss in decibels.

Case 2: Mr. F. K., aged 49, complains of head noises referable to both ears. On measurement, the tinnitus was found to be at the level of 8,192 d.v. There is a history of progressive deafness since childhood. Otoscopy and nasopharyngoscopy gave normal findings. Rinne is negative and the loudness balance test shows no recruitment.

A hearing aid with greater amplification of the higher frequencies in the speech range was fitted to the right ear, but the patient obtained considerable relief from tinnitus in both ears.

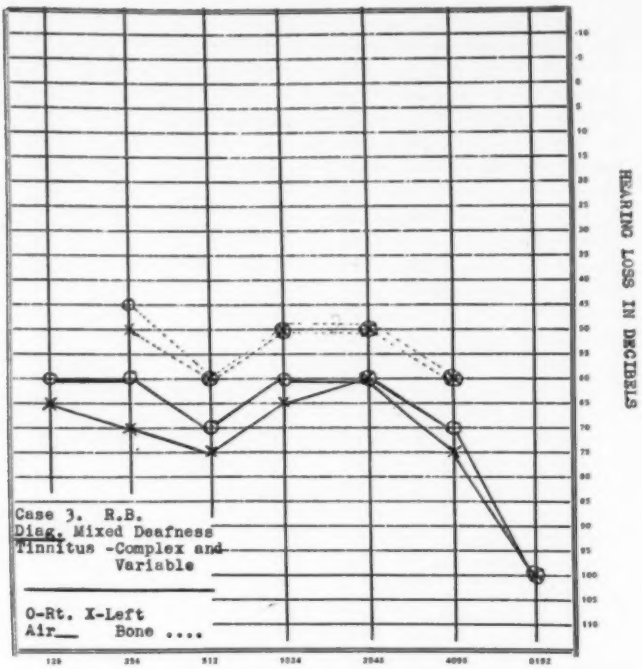

Fig. 3. Hearing loss in decibels.

Case 3: Mrs. R. B., aged 54, complained of most distressing tinnitus in both ears. No measurement of her tinnitus could be obtained. She had discharging ears in childhood and young adult life, but in recent years the ears remained dry. Otoscopy reveals the almost complete absence of drums, while the inner walls of both middle ears are greatly thickened and parts of the ossicles are visible through meshes of fibrous bands. Rinne is ± and no consistent responses could be obtained with the loudness balance test.

A hearing aid with "flat" amplification and a spliced cord for receivers to both ears gave the patient relief from her tinnitus, in addition to improvement in hearing.

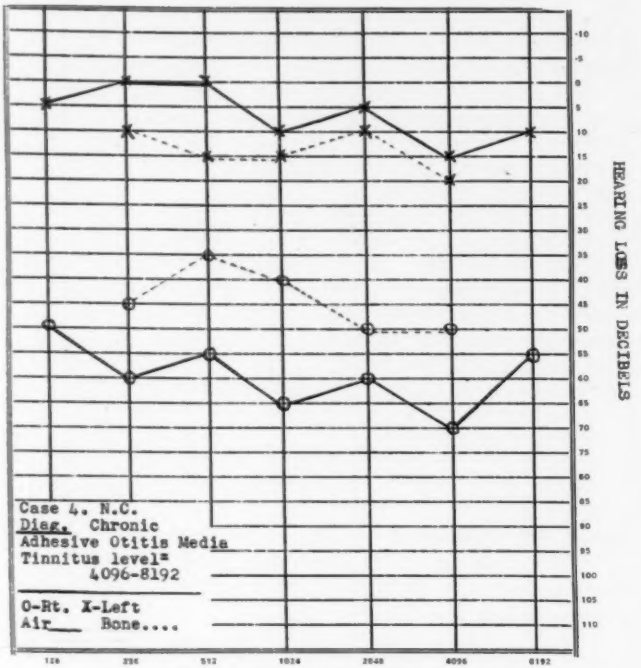

Fig. 4. Hearing loss in decibels.

Case 4: Mr. N. C., aged 33. History of a "running" right ear ever since childhood and deafness in this ear as long as he can remember. Distressing tinnitus is present in this ear from time to time and is never free from it entirely. The patient is also unable to localize sound coming from the direction of his right ear. Otoscopy reveals the drum in the right ear retracted, scarred and plastered to the inner wall of the middle ear. Nasopharyngoscopy disclosed no abnormality. Tinnitus is at the level of 4,096-8,192.

A hearing aid with "tilted" amplification towards the higher frequencies in the speech range gave the patient relief from his tinnitus and he was able to localize the source of sound accurately when the instrument was worn.

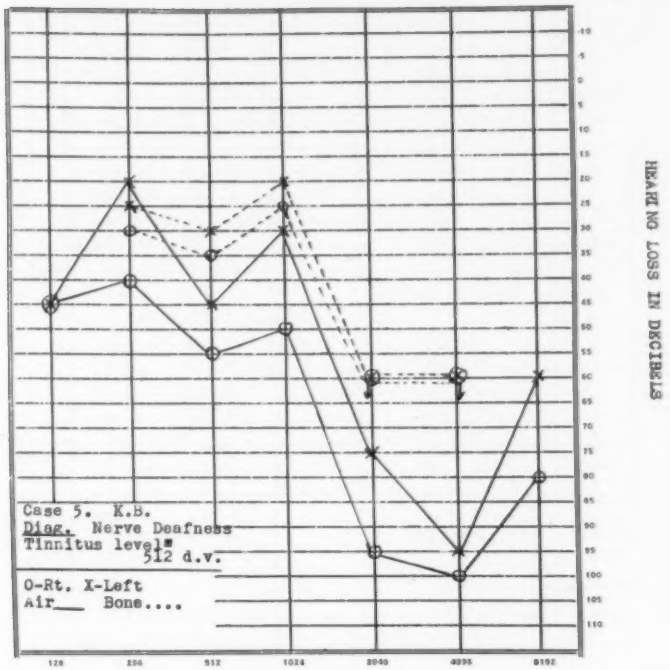

Fig. 5. Hearing loss in decibels.

Case 5: Mr. K. B., age 40, states that his hearing difficulties date back to 1940-1941, when he began working as a riveter in a shipyard. At that time, head noises would annoy him in the quiet of the night, but in recent months the tinnitus in his right ear became most distressing. Otoscopy and nasopharyngoscopy revealed no abnormality. The level of the tinnitus is at 512 d.v. Rinne is positive and the loudness balance test shows recruitment.

A hearing aid with greater amplification of the higher frequencies in the speech range was fitted to the right ear and the patient is greatly relieved from his head noises.

Comment: In the physical aspect of tinnitus, bone conduction is an important factor. The individual whose ear is deaf to air conducted sound from the outside will hear noises arising in his own body—from muscle action of his pharynx and chest and blood vessel murmurs — by the bone conduction route. When this patient is fitted with a hearing aid, and extraceptive hearing is restored, his body bruits will fade into the background.

The type of tinnitus which is due to action potential of the cochlea, auditory nerve or cortex may be relieved by masking. Josephson[1] was able to drown out head noises by his ingenious sound producing instruments. His method consisted of raising the superimposed sound to a sufficiently high level to subdue the patient's tinnitus; however, the more recent procedure in masking is to make use of both physical aspects of sound — frequency and intensity — in such a way that a desired specific sound tone is rendered inaudible. The rules governing this process, as summarized by Stevens and Davis,[2] are that a loud tone masks tones higher than itself more easily than it masks lower tones, and that masking is greater when the tones lie close together in frequency. By the light of these scientific facts, the mode of action of a hearing aid in masking tinnitus is greatly clarified. In a majority of cases, the low pitch head noises fall within a frequency range of 100-200 d.v., while the high pitch group is usually at the level of 5,000-8,000 d.v. Either variety is, therefore, at the outside fringe of the speech range. A hearing aid that will amplify frequencies 512 and 1,024 d.v. to the extent of 40 db. will cut out low pitch tinnitus most effectively. Similarly, an instrument which will amplify 2,048 and 4,096 d.v. to the intensity of 40 db. will drown out high pitch tinnitus readily. Specific models of hearing aids are available to work effectively in most cases and the unusual problem arising when an individual has tinnitus at the level of the middle frequencies may be solved by a custom-made hearing aid. The ideal outside sound to play on the hearing aid and ear for drowning out intrinsic tinnitus is human speech. Besides its favorable physical aspects, it has the psychologic advantage of

occupying the patient's attention; however, the spoken voice is not available to act upon the ear constantly, and we must rely upon the ever present noise which, according to Fletcher,[3] lies within the frequency range of 64-4,096 d.v. By amplifying certain bands of it, the patient's tinnitus, whether it be of physical or hallucinatory origin, will be subdued, and the remarkable fact is that extraneous "noise" is more readily tolerated by the human nervous system. Through the era of civilization the inner ear has been conditioned to dampen and tolerate the "noise from the environment, but is disturbed by the least amount of tinnitus that arises within it.

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